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Climate and Crime: Examining the Relationship Between Extreme Weather Events and Crime Rates in the United States

Erin Tully

Claremont McKenna College

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Erin Tully

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Abstract

This study attempts to determine whether there is a relationship between extreme weather events and crime rates. Due to the increasing effects of climate change, it is critical we understand the societal effects of extreme weather. Here, a panel data fixed effects regression was used to analyze state and year level data. It was hypothesized that there would be a relationship between crime and extreme events, but the results did not show a statistically significant relationship. Further research with increased geographic and temporal controls is encouraged.

I. Introduction

Man-made climate change has been often cited as one of the greatest threats to our world today (World Economic Forum 2018). World leaders, nonprofit groups, and the majority of peer-reviewed research all argue that climate change is a concern that needs to be addressed and addressed soon (Cooke et. al 2013, 7). Arguably the consequences of allowing climate change to continue unimpeded are severe and affect almost every facet of life as we know it. Higher temperatures, ocean acidification, warming oceans, sea level rise, and an increase in frequency and severity of extreme weather events are only some of the threatening effects of a changing climate (Melillo 2014, 32-101). These effects could have disastrous consequences, including forced migration, lowered food production, social unrest, and severe health crises. All these consequences can work in conjunction to threaten the livelihood of millions of people (IPCC, 2014). As people face food shortages, health issues, and forced migration, infrastructure will be overloaded, and the economy will suffer (Tol 2009, 29-51; Piguet 2008, 10-11).

One of the major effects of climate change is an increase in frequency and intensity of extreme weather events (Kundzewicz 2017, 9-10). Extreme weather can include avalanches, droughts, heat waves, flooding, hurricanes, and other intense and potentially damaging weather. Obviously, not all extreme events are tied to climate change, and one of the challenges facing scientists is determining the strength of the effect of climate change on weather events (Meehl et. al 2000, 8-9). Of all extreme weather events, heat waves, flooding, extreme precipitation, and droughts are the most strongly linked to climate change, while tornados and hurricanes have a weaker link (Murray 2012, 759-760).

The link between climate change and extreme heat is most clear, as greenhouse gases have the effect of causing global warming (Luber 2008, 6). In discussing this topic, it is important to clarify that this paper uses the word “climate” to include climatic variables such as temperature, rainfall, and natural disasters.

The number of heat waves has been increasing in recent years, a trend that has continued in 2017 and 2018. In the 1950s, daily record high and low temperatures occurred with a similar frequency. In the past decade, daily record high temperatures occur twice as often as record lows. Scientists expect that this ratio will continue to increase, with record high occurring twenty times as often as record lows by 2050 (Center for Climate and Energy Solutions 2017). Extreme precipitation is also strongly linked to climate change, as warmer air can hold more water vapor (Center for Climate and Energy Solutions 2018). For each one degree increase in temperature, the air contains up to 7% more water vapor. With more moisture in the air, more intense precipitation is possible. Conversely, more intense precipitation does not necessarily lead to a total increase in precipitation, as models predict rain to fall less often. Along with many other regions of the world, the United States has seen an increase in the intensity and frequency of extreme precipitation events, with the Midwest and Northeast being the most strongly affected. Scientists are less certain about the effect of climate change on hurricanes, specifically whether it will lead to an increase in the number of hurricanes. However, scientists do expect warmer ocean temperatures and higher sea levels to intensify the effects of hurricanes. Recent studies of the strongest hurricanes in the past two to three decades find increased intensity. Models of hurricane intensity in the United States Atlantic Basin predict an increase in more severe hurricanes and a reduction in less severe hurricanes (Knutson et. al 2013, 23-26).

Extreme weather events have a number of negative effects. By their nature, they cause damage to the areas in which they occur, whether it is damage to the ecology, human population, or human property. Heat waves, for example, can cause an increase in other disasters such as drought or wildfires. Heat waves are the deadliest natural disaster in the United States, killing around 600 people on average per year. This is greater than the number killed from hurricanes, lightning, tornadoes, earthquakes, and floods combined (Center for Climate and Energy Solutions 2017). Heat waves can also damage agriculture, as both crops and livestock suffer from heat stress (Rosenzweig et. al 2001, 14-15).

Heavy precipitation can also threaten the areas it affects. Most obviously, flooding is likely from an extreme precipitation event, especially if it occurs after a dry spell. Along with flooding, extreme rain increases the chance of landslides, by raising the water table, saturating the ground, and causing slopes to lose stability (Center for Climate and Energy Solutions 2017). The runoff from rain contains pollutants like heavy metal and pesticides, which can end up in water systems. These pollutants can harm both human health and ecosystems.

Hurricanes often cause extreme amounts of damage to the entire area they affect. Hurricane Katrina alone cost $125 billion in damages (Center for Climate and Energy Solutions 2017). The powerful winds and rain in hurricanes can cause flooding, destruction of property, and loss of life. The immediate effects of these events are well documented, but they also have more subtle and long-term effects. Extreme weather events can exacerbate problems of social instability, especially if people's homes or livelihoods are damaged by the event. Appropriative behavior is often an issue after hurricanes, as people scramble to find supplies and others take advantage of the overwhelmed police services (Trainor 2006). Understanding the societal effects, such as crime, is critical to designing policy to combat them and to adapt to them.

Even as concern over the effects of climate change grows, some continue to argue that the effects are not that great, and that our immediate economic interests are of far greater importance[1]. Despite the clear scientific consensus, many still doubt either the existence or the negative effects of climate change (Dunlap and McCright 2010, 16-17). In order to properly combat climate change, it is critical that legislators act quickly to help mitigate human effects on the climate and help us adapt to the changing world. For them to get going, they must be educated on the consequences of failing to act and the ways in which we can improve.

There is a long history of investigating a possible link between change in climate and change in level of crime. In the late 1990s and early 2000s, there was an influx of studies investigating this link. Most studies to date have focused on the effects of temperature and rainfall. There is a general consensus that increased temperature and increased rainfall are correlated with higher rates in crime and violence. However, to the best of my knowledge, none of these studies looks at the relationship between extreme weather events and crime. In addition, many of these studies use data from 20 or more

[1] Foran, Clare. "Donald Trump and the Triumph of Climate-Change Denial." The Atlantic. December 25, 2016. Accessed March 28, 2018. https://www.theatlantic.com/politics/archive/2016/12/donald-trump-climate-change-skeptic-denial/510359/.

years ago (Hsiang and Burke 2014, 6-13). This paper intends to add to the existing literature by investigating the effects of all extreme weather events in the most recent period analyzable, across the United States. Policy on crime and climate are constantly changing, and it is important to show that this is a relevant issue, both temporally and spatially. This paper will provide valuable information to policy-makers and to the general public, allowing them to make more robust analyses of the value of climate policy.

Specifically, I investigate the relationship between nine different types of crime rates and the total number of extreme events over the past two decades within the United States. I include 47 different types of weather events from 1994-2014, 9 types of crime, and 3 demographic controls. Overall, I found that the relationship between extreme weather events and crime rates were insignificant. Even in situations where some types of extreme weather were significant, their values were so close to zero in magnitude their effect would be null. The total number of events were never significant. This may be because some types of events have a negative effect on crime, while others have a positive one. On average, the effects of total events would be averaged out.

In Section II, I discuss the available body of research on the issue of climate variables, crime, and the behavioral effects of weather. In Section III, I discuss the three sources of data used for this paper and give descriptive analysis. In Section IV, I describe the empirical model for this analysis and the results it yielded. In Section V, I discuss the intuition and reasoning behind the results. I also describe limitations on my study and possible future research into the topic.

II. Literature Review

The subject of climate and conflict received little attention in the academic literature until around 20 years ago. The one exception to this is the literature discussing the relationship between heat and aggression (Kendrick and McFarlane 1986). Data on temperature is much easier to gather than many other variables such as hurricanes tornados, and casual empiricism suggests that people become angrier at higher temperatures. As many of these studies note, there is a cultural linkage between temperature and anger, citing common phrases such as “feeling hot under the collar” and “temperatures flaring” (Anderson and Anderson 1984, 91). Links between temperature and destruction have been analyzed since the early 1900s. The earliest papers focus on historical analysis (Huntington 1917, 173-208), and do not use statistical analysis, but rather rely on historical phenomenon and draw links using logical reasoning. Even some recent essays focus more on discussion and linking the known effects of some occurrences (such as ozone depletion) to the unknown causes of other phenomenon (like regional violence) (Levy 1995, 23-24).

Econometric analysis of the temperature-aggression relationship began the mid to late-1900s and focus on various measure of aggression such as use of car horns (Kendrick and MacFarlane 1986, 9-11) or domestic violence (Auliciems and DiBartolo 1995, 2-6). Many of these early studies use basic regression analysis to identify trends in gathered data. Most of the analyses look at the effect of day-to-day effects of warmer or cooler temperatures on specific instances of violence. In general, studies on the link between various kinds of rough behavior and temperature surged in the late 1900s. Several focus on the link between temperature and aggression (Anderson and Anderson 1984, 91; Baron and Lawton 1972, 3; Anderson et al. 2000, 63-133). Others look more at more specific types of violence, such as assault (Cohn and Rotton 1997, 1322; Harries and Stadler 1983, 235-256), deadly assault (Anderson et. al. 1997), collective violence (Baron and Ransberger 1978, 351-360), crime rates (DeFronzo 1984, 185-210; Field 1992, 340-351), and police officer violence (Vrij et. al 1994, 365-370). Very few of these studies look at the effect of cumulated extreme temperatures, instead focusing on individual incidents. Possibly because the field was in its infancy, many of these studies analyze their data in similar ways, identifying variables and running basic linear regressions. However, some of them stood out in terms of their analysis style. Anderson et al. (1997) uses latent variable analysis. These papers show an increase in interest in the subject and more complex analysis that reveal more subtle results. Later, Anderson et al. (2000) perform one of the first meta-analyses in this subject, looking at only about 10 studies, but using effect size calculation and categorization. This is important because it shows there are enough studies to determine if there is a scientific consensus on the topic. These early meta-analyses found a consistent link between heat and violence.

Since the turn of the century, studies have become broader in nature, starting to look at the effects of climate variables on places around the world, and on a wider variety of types of aggression. Some studies focus on specific phenomenon, such as the El Nino (Davis 2001, 1368-1379; Grove 2007, 318), while others focus on general effects of climate change (Gleditsch 2012, 3-9 Scheffran et al. 2012). They also began focusing on various places during various periods of time. Some focus on early human history in places such as the Akkadian Empire (Cullen et al. 2000, 379-382), Mayan Civilization

(Haug et al. 2003, 1731-1735), and Angor, Cambodia (Buckley et al. 2010, 6748-6752), or simply long periods of early history (Iyigun 2017). Others focus on more modern, very specific locations like India (Blakeslee and Fishman 2014, Iyer 2014), Mexico (Baysan et al. 2014), the Philippines (Wetherley 2014), Indonesia (Caruso et al. 2014, 66-83), and specific regional areas of the United States (Rotton and Cohn 2000, 1074; Jacob et al. 2007; Mares 2013, 768-783; Ranson 2014, 274-302). Still more looked at climate variables other than temperature, focusing on rainfall (Hidalgo et al. 2010, 505-523; Hendrix and Salehyan 2012, 35-50; Sarsons 2015, 62-72), water availability (Levy et al. 2005, 21; Couttenier and Soubeyran 2014, 201-244; Maystadt and Ecker 2014, 1157-1182; Theisen et al. 2011, 76-106), or weather shocks in general (Auffhammer et al. 2013, 2-6; Jia 2014, 92-118). The literature does not extensively address the effects of natural disasters or climatic disasters on violence, with the exception of Wetherley 2014. Most of the literature looking at natural disasters looks at specific results of those disasters, such as increased temperature of cyclones (Hsiang 2010, 15367-15372), looks at effects other than violence, such as economic growth (Bergholt and Lujala 2012, 147-162), or looks at very specific events (Hsiang et. al 2011).

One paper by Matthew Ranson performs analysis similar to mine (Ranson 2014, 274-302). Ranson estimates the effect of climate change on criminal activity in the United States. He found that temperature has a positive effect on all types of criminal behavior. Specifically, he found that the largest marginal effects were below 50 °F. His analysis uses the same database of criminal activity but different weather measures. Ranson focuses on temperature and rainfall, rather than extreme events. He also focuses on the county level, rather than the state or national. He does so in order to assist in empirical identification of how weather affects crime rates. I choose to focus on the state level to make a practical examination of more weather types. Further research would ideally look into county-level data for my analysis.

Despite the lack of early studies, the literature on climate and conflict has now grown so prolific that several meta analyses have been published, focusing on gathering the existing literature and either summarizing it or performing greater statistical tests on the broad data (Gleditsch 2012, 3-9; Hsiang et al. 2013, 1-14; Hsiang and Burke 2014, 6-13; Burke el al. 2015, 577-617). These meta analyses gather over 50 studies on the subject and attempt to determine whether there is a consensus in the literature. The more recent meta analyses show that there is broad agreement that climate change causes increased rates of human conflict (Hsiang and Burke 2014, 6-13).

III. Data Section

I use three data sources to analyze the relationship between extreme weather events and crime. The first data set is from the National Centers for Environmental Information's (NCEI) National Oceanic and Atmospheric Administration (NOAA). The This NCEI receives storm data from the National Weather Service, which in turn receives their information from a variety of sources. These sources include county, state and federal emergency management officials, local law enforcement officials, skywarn spotters (a network of citizen dedicated to gathering weather information), NWS damage surveys, newspaper clipping services, the insurance industry and the general public, among others. The dataset tracks extreme events across the United States from 1950-

2017. It defines the type of events it tracks as “destructive storm[s] or weather. It is usually applied to local, intense, often damaging storms… but it can also describe more widespread events.” This dataset is a collection of individual events, with a unique entry and id number for each (National Oceanic and Atmospheric Administration. 1950-2018). The dataset includes several important variables including location information, the type of extreme event, fatalities caused by the event, and estimated damage caused by each event.

For this dataset, variation across states was high. Texas had by far the highest 20-year average of total weather events at 3963.905. The next highest state, Kansas, was nearly half of that, at 2614.381. The District of Columbia, at the far end of the other extreme, had an average of 70.905 total events over 20 years. It must be noted, however, that the District of Columbia and two other states, have some years in which there are no recorded events. Both the District of Columbia and Alaska are missing events for 1994 and 1995, while Hawaii is only missing events for 1994. The number of extreme events, collected beginning in 1950, increases drastically over time, most likely due to better tracking mechanisms. However, in the last couple decades, the number of reported events has become much more stable. Thus, the chosen time period of 1994-2014 does not have as much variation in observed events. Even so, the number of events more than triples over this period. Because this analysis looks at within-state variance, this shift should not affect the results.

The unit of analysis is the state and year from 1994 to 2014. The final sample includes 47 types of extreme events (for example, extreme heat, flooding, hurricane, and blizzards). To use this data, I first dropped most of the details of the extreme events, like location and damage, with the exception of the total injuries and deaths caused by the total extreme events in a year. I then reshaped the data so that it had a sum of each type of event for each state year. In this analysis, I use five weather types: heat, heavy rain, floods, drought, and total extreme weather events. I created the variable total events, simply by summing all the event types into one variable. I also created the variable total events to look at the effect of all the events at once. Table 1a shows the descriptive statistics for the weather events used in my regressions, include the mean, standard deviation, and the minimum and maximum.

The second dataset is from the FBI's Uniform Crime Reporting Statistics which tracks the rate of crimes across the United States from 1960-2014 (Uniform Crime Reporting Statistics. 1994-2017). In particular, it tracks nine different types of crime rates: assault, burglary, larceny, motor vehicle theft, total property crime, robbery, murder, rape, and total violence. All are measured in number of incidents per 100,000 people. This data is provided by contributing law enforcement agencies, which FBI provides with handbook that explains how to classify and score offenses and provides uniform crime offense definitions. Thus, the definitions used for these crimes is the federal one, rather than state or local definitions. To clarify some of the crimes with similar colloquial usages, I will provide their definitions. Burglary is synonymous with breaking and entering; that is, the unlawful entry of attempted entry of a structure to commit a felony or theft. Robbery, on the other hand, is defined in the more colloquial sense as the taking or attempted taking anything of value from another person or persons by force or threat of force or violence and/or by putting the victim in fear. Larceny-theft is distinct from robbery in that the unlawful taking is not done through force, violence, or fraud, e.g. shoplifting or pickpocketing. Motor vehicle theft is similar to the last two but applies only to motor vehicles and applies to both forceful and non-forceful takings. Violent crime and property crime are similar in that they are both the sum of their type of crime. Violence rate includes murder, assault, rape, and robbery, while property crime rate includes burglary, larceny, and motor vehicle theft.

The rate of total violent crime has a general downward trend from 1994 to 2014. The average rate of violent crime in 1994 is 594.24 crime per 100,000 people across the United States. Despite a slight increase in 2006, it decreases steadily until 2014, where the rate is 364.41. The overall property crime rate has a similar trend, although the rates are far higher than the rates of violent crime. In 1994, property crime occurs at a rate of 4488.58. It falls steadily, almost halving in 20 years, reaching 2603.5 in 2014. There is a high variance in the 20-year average of crime rates across states. The District of Columbia has by far the highest average rate of both violent and property crime. Its property crime rate, at 6003.05, is more than double any other state. The effect is less dramatic for violent crime, where the District of Columbia's rate of 1633.67 is only 20% higher than the next highest state. The states with the next highest crime rates seem to follow no pattern, occurring across the spectrum of size, political allegiance, and United States geography. The states with an average violent crime rate over 700 are, in order of decreasing crime rate, South Carolina, Florida, New Mexico, and Tennessee. The list is slightly different for property crime, with the four states with the next highest crime rates after D.C. being Arizona, Florida, Hawaii, and Washington. The two types of crime show more geographic homogeneity at low rates, with most of the states with the lowest rates are located on the east coast. The states with the lowest average property crime rates, just over 2000, are South Dakota, North Dakota, New Hampshire, and West Virginia. Those with average rates of violence under 200 are Maine, Vermont, North Dakota, and New Hampshire.

The data for all these crime measures was collected individually, by state and by year. They were then reshaped in Stata to provide a sum of that crime rate for each state year and merged with the weather data using the state fips. Table 1b gives the descriptions of these crime rates mean, standard deviations, and min and max.

The third dataset is from the U.S. Census Bureau which includes three demographic variables: income, unemployment, population, and education (American Fact Finder. 2017). These were all gathered from the American FactFinder.

The average population the fifty United States increases over time. In 1994, the average population (in 100,000s) is 5104.451, and consistently decreases to 6247.500 in 2014. California and Texas have the highest 20-year average populations, while the District of Columbia and Wyoming have the lowest averages. Unemployment has a far less consistent trend over the 20-year period. It hovers around 4-5 from 1994-2008 and jumps to almost 9 in 2009. It decreases steadily from there and goes back down to near 5 by 2014. Connecticut, California, and Arkansas have the highest 20-year average of unemployment, while North Dakota, Nebraska, and South Dakota have the lowest. The median income steadily increases over the 20-year period. The average over the United States started at 32,420 in 1994 and steadily increases to 55,224 in 2014. The states with the highest average median income over the two decades are Alaska, Connecticut, Maryland and New Jersey. Those with the lowest average are Arkansas, Mississippi, and West Virginia.

This dataset was treated in the same manner as the previous variables. I collapsed these variables into a by state year dataset covering all fifty states from 1994-2014. I then merged it with the other two databases by state and year. Table 1c shows the descriptive statistics for the demographic variables.

IV. Empirical Strategy and Results

I estimate a fixed effects panel model, where I regress crime in state i and year t, on extreme weather in state i and year t, demographic controls, state fixed effects, and year fixed effects. Thus, I have a separate regression for each type of crime. I include demographic controls in each regression: population, income, and unemployment. I also have a separate regression for four types of weather events, specifically ones that have been shown in past research to be more strongly associated with climate change. I use the equation:

$$crimerate_{it} = \beta_{\mathrm{it}}\mathrm{weatherevents} + \alpha_{1\mathrm{it}}\mathrm{income} + \cdots + \alpha 3\mathrm{itPopulation} + \delta_{\mathrm{t}} + \gamma_{\mathrm{i}} + \mathrm{u}_{\mathrm{it}}$$

where crimerate_{it} will be substituted for each of the nine types of crime rates, $\beta_0$weather_events will be substituted with the total number of each of the five types of weather events. δ_1 denotes fixed effects, γ_i denotes state fixed effects, and u_{it} is the error term. Tables 4-12 show the results of each regression for each type of crime rate. Overall, the results fail to detect a consistent relationship between weather events and crime rates.

Overall violent crime rates (Table 4) is not significantly affected by any of the types of weather events. In addition to not being significant, the effect of weather events does not have a consistent trend. Three of them (total events, drought, and rain) are positive, while floods and heat are negative. However, these mixed trends do not have much of an effect, as all the weather events had coefficients very close to zero. Only rain events has a coefficient above 0.1, as a 1% increase in events of heavy rain is associated with an increase in rates of violence of around 0.163 per 100,000 people. The only significant variable for violence rates is population (in 100,000s), which is significant for every single type of weather. As population increases by 1%, rates of violence decrease by around 3.4 per 100,000 people. The other two demographic control variables are insignificant, although both have larger coefficients than any of the weather event types.

For assault rate (Table 5), none of the types of weather are significant, and the coefficients remain near zero. Although insignificant, rain was again the weather event with the strongest correlation, correlated with a 0.14 increase in assault rates. For this crime type, two of the demographic controls are significant, population and unemployment. For all five of the weather types, as population increases, the assault rate decreases by around 2.5. Unemployment also appeared to decrease the assault rate for all of the weather types, by around 8.2. This is a surprising result, as casual empiricism would suggest that increasing unemployment would occur increase crime rates. Income was insignificant, but also strongly correlated. Although insufficient, it had a larger coefficient than any of the weather events, increasing assault rates by around 1.1.

Murder rate (Table 6) was only significantly affected by one variable. The one significant variable was floods, which negatively affected murder by -0.0008. Given the smallness of this number, the effect of floods is essentially zero. Murder is distinct from the other crime rates in that the coefficients of every single variable were essentially zero. Not a single variable, including demographic controls, had a coefficient higher than 0.1.

The next type of crime, rape (Table 7), is notable in that it is the only crime significantly affected by income. Income (in 1,000s) is associated with increased crime rates for all weather events of around 0.26. Population is also significant, but only for total events, where it negatively affects crime by around 0.1. For the other event types, population is only significant to the 10% level. Total weather events significantly affect rates of rape, and two other types (rain and floods) are significant at the 10% level. However, all three coefficients are very close to zero. Total weather events increase crime by 0.002, increased rain is associated with an increase in crime of 0.019, and floods track with a 0.005 increase in crime.

Robbery rates (Table 8) are not significantly affected by any of the variables. Both heat and drought events are significant at the 10% level. A 1% increase in drought is associated with a 0.017 increase in robbery rate, while heat is associated with a 0.037 decrease. Weather types continue to have mixed effects on crime, with total events, heat, and floods being negative, and drought and rain being positive. Again, although insignificant, all of the demographic controls have larger coefficients than any of the weather types. Population negatively impacts robbery by 0.666, while both unemployment and income positively affect crime by 3.126 and 0.366, respectively.

Property crime (Table 9) is also not found to be significantly correlated with any variables, either weather events or demographic controls. Rain remains the event with the highest coefficient, however, negatively affecting property crime by around 1.25. Although not significant, unemployment has an extremely high coefficient, increasing property crime by around 36. Population and income also have a stronger impact on property crime than any other the weather events, but both are negatively correlated.

Burglary rates (Table 10) had similar results, in that none of the variables are significantly correlated with burglary rates. Even the coefficients of weather events remain low, around zero. Again, the strongest correlation (but still insignificant) is in rain events, which were slightly negative, decreasing burglary rates by around 0.15. The coefficients of the demographic controls remain higher than those of the weather types. Income and population show negative correlations of around 3 and 2, respectively, and unemployment has a positive effect of around 7.8.

Larceny rates (Table 11) has the first significant correlation with weather events with a coefficient that is not essentially zero. Rain events and flood events are both were significant at the 5% level, with rain decreasing larceny by around 1.3. This is still contrary to expectations, however, as the existing literature agrees that heavy rain is associated with higher rates of crime. Flood events also significantly affect larceny rates, but at a much lower rate. As flooding increases by 1%, rates of larceny increase by 0.17, which is more consistent with past analyses. None of the demographic controls are significant at the 5% level, but unemployment is significant at the 10% level for total events, rain events, and flood events. The coefficient of unemployment for these is very high, right around 29. Income and population were not significant, but both were negative with relatively low coefficients.

Total events were the most significant in relation to motor vehicle theft (Table 12), associated with an increase at the 1% significance level. This coefficient is still very close to zero, only associated with a 0.037 increase in motor vehicle theft for every 100,000 persons when total events increase by 1%. As drought events increase by 1%, motor vehicle theft increases by 0.061, but only at the 10% significance level. None of the demographic controls affected motor vehicle theft, and they have lower coefficients than for many of the crime types. Income increased crime rates by around 0.5, while population decreased it by around 1.6.

Contrary to expectations and past literature, most of the crime rates were not only not significantly affected by weather events, but consistently had very low coefficients. Because almost all the coefficients were so close to zero, it was difficult to identify a positive or negative trend. Even in instances when weather events were significant, their coefficients were small enough to render the results effectively null. This trend of an inconsistent trend held true for the demographic controls as well, which alternately have negative and positive effects and lower and much higher coefficients.

Robustness check

I performed three tests to check for robustness in my analysis. These tests are intended to rule out a possible omitted variable, check the effect of time, and the effectiveness of a control variable. The first robustness check runs the regression with the demographic control variable education included. The second uses a time trend instead of year fixed effects, and the third runs the regression without the demographic control population. For all three, I re-ran the models for the two buckets of crime, violent crime rates and property crime rates.

The U.S. Census Bureau data on educational attainment is only available for a subset of the years covered in this analysis. The existing data covers 2006-2012, which is only 7 of the 20 years this regression includes. Thus, it did not make sense to include this variable in the entire analysis. However, education may be an important factor in explaining variation in crime rates. Therefore, I restrict attention to the 7 years for which I have data on education and re-estimate my models to see if the results are change. The measure of education used in this analysis is percentage of the population 25 years and over that have graduated from high school. When running the regression with education included, I found very little change for violent crime (Table 13). While population was no longer significant at the 5% level, it was still significant at the 10% level. None of the variable coefficients change much, or change sign. Education was not significant, but did have a strong negative coefficient, around 9.7 for all weather types. This is consistent with casual empiricism, which would suggest that increased education would decrease violence. There is a little more difference when using education in the regression for property crime (Table 14). When controlling for education, population becomes significant, negatively affecting property crime rate by around 13, almost double the effect when not controlling for education. Income and unemployment do not become significant, but their coefficients do change dramatically, to the point of changing signs. Education is not significant, but does have a strong negative effect on property crime rates of around 21.

I also re-estimate the models excluding the demographic control population. Because the crime rate variables are already scaled by population, I am testing to see whether or not excluding them as a control impacts my results. The regression, when run without population, was not significantly different. The results for violent crime were very similar, the only major difference being that population becomes significant (Table 15). However, the coefficient does not shift dramatically, and none of the other variables change much. The results for property crime were also essentially the same (Table 16). None of the variables became significant, and none of their coefficients changed to a large degree.

Lastly, I re-estimate the models using a time trend instead of year fixed effects. This explores whether assuming a linear trend (the time trend) as opposed to the time fixed effects changes my results. I ran two types of crime using time trend, the overall violent crimes rate and the overall property crimes rate. The results were not very different for the rate of violent crime (Table 17). The only major difference is that flood events are significant when run with the time trend effect, decreasing the rate of violent crimes by 0.072. No other variables changed in significance, and most stayed static in terms of coefficients. Unemployment did change in sign, from -4.823 using year fixed effects to 1.645 using a time trend. The results for property crime were also rather similar, with the only difference being that the effect of unemployment becoming significant (Table 18). Even with the change in significant, the coefficient of unemployment remained similar, moving from around 36 to around 27. Thus, it seems that the effects of year fixed effects and a time trend are not significantly different.

V. **Conclusion**

Many studies have found that increased levels of rain and heat cause an increase in crime rates and violence. This is a concerning trend, especially as climate change continues to intensify the strength and number of extreme weather events. However, regulation preventing climate change continues to be controversial and experts say that they are insufficient to stem the effects. To institute proper regulation, cost-benefit analyses must include all the effects of climate change, one of which is increased violence from high heat and increased rain. Thus, it is important to know if whether or the extent to which extreme weather events are related to crime rates. If they are associated with higher rate of crime, the costs of climate change are even higher than before, and regulation is an even more pressing matter.

This study, however, finds little to no relationship between all extreme weather events and any crime types. It also fails to find links between extreme heat and crime and heavy rain and crime, which are consistently found to exist in existing literature.

It is possible that this is due to the methods used in this study. Because this study looked at the within state variation, which is a large geographic area, it is possible that geographic information was left out that would have revealed nuances of the effects of weather on state-level crime. This analysis also looks at variation within year, which is a large span temporally. There may be significant other variables within each year for which this analysis does not account. It is also possible that there is other omitted variable bias that this study did not account for, as it only controlled for three demographic variables.

Due to the nature of extreme weather events it is also possible that crimes would go unreported. For one, people would be in a high stress situation and may not have the time or mental space to report crimes. For another, for weather events such as floods, people may not know what of their belongings were lost in the weather event and what was stolen. These conditions may make it harder to measure the effects of extreme events.

The extensive past research on heat and rainfall has a relative consensus that high heat and rainfall increase crime rates. Thus, it is unlikely that, as this study shows, there is no effect of extreme weather on crime. Additional research should be done on this topic, using more detailed geographic information. It should locate the weather events on a county basis and include control demographic variables on county-level statistics. This would allow the study to control for more geographic differences that may have affected the results. It makes sense that looking at the state level, differences in lower-level geographic areas could make the results less significant.

Following the results of past research, it is clear that more regulation of climate change is needed. Much of the literature shows that climate change is increasing extreme weather, and extreme weather increases crime. This violence, loss of human life, and monetary cost, should be integrated into cost-benefit analyses of regulation. Once it is, it will be clear that it is critical we must act to slow the effects of climate change.

Table 1: Descriptive statistics of crime rates

Variable	**Mean**	**Std. Deviation**	**Min**	**Max**
Violence Rate	445.9215	265.7202	66.9	2662.6
Assault Rate	282.6109	161.3674	34.1	1441.8
Burglary Rate	732.2903	264.7023	257.2	1838.4
Larceny Rate	2420.224	687.4296	1160.8	5833.8
MV Theft Rate	344.9486	227.0699	38.9	1839.9
Murder Rate	5.625957	5.891078	0.2	73.1
Property Crime Rate	3497.463	1061.466	1524.4	9512.1
Rape Rate	34.07096	11.92828	9.7	93.3
Robbery Rate	122.5353	114.4977	6.4	1239

Table 2: Descriptive statistics of weather events

Variable	Mean	Std. Deviation	Min	Max
Total Events	844.1536	825.7011	1	5582
Drought Events	36.13445	127.3216	0	1845
Flood Events	80.58824	118.138	0	1345
Heat Events	17.26127	44.44825	0	432
Rain Events	13.04507	26.55835	0	400

Table 3: Descriptive statistics of demographic variables

Variable	Mean	Std. Deviation	Min	Max
Population (in 100000s)	57.07355	63.78452	4.74982	387
Income (in 1000s)	44.71272	9.608257	23.564	76.165
Unemployment	5.63615	1.924597	2.3	13.65833

Table 4: Effect of Weather Events on Violence Rates

Violent Rate	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
# Total Events	0.0063753 0.0141654				
# Drought Events		0.0362929 0.0257264			
# Heat Events			-0.0284155 0.0798465		
# Rain Events				0.1626216 0.1357977	
# Flood Events					-0.0375565 0.0302868
Income	1.670024 3.184576	1.690005 3.204764	1.627125 3.204391	1.671362 3.187211	1.597386 3.202578
Population	-3.211704** 1.465661	-3.415674** 1.486354	-3.183361** 1.47692	-3.2722** 1.494989	-3.190398 ** 1.473439
Unemp	-4.823267 5.232743	-4.4237 5.208266	-4.783009 5.248325	-4.740565 5.16253	-4.764791 5.239642

Notes: Standard errors are reported in parentheses. One, two, or three asterisks indicate statistical significance at the 10-, 5-, and 1-percent levels, respectively.

Table 5: Effect of Weather Events on Assault Rates

Assault Rate	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
# Total Events	0.008 (0.010)				
# Drought Events		0.017 (0.018)			
# Heat Events			0.004 (0.058)		
# Rain Events				0.141 (0.099)	
# Flood Events					-0.026 (0.021)
Income	1.115 (2.246)	1.095 (2.265)	1.071 (2.263)	1.102 (2.251)	1.044 (2.260)
Population	-2.408** (0.914)	-2.477** (0.954)	-2.370** (0.937)	-2.448** (0.953)	-2.376** (0.934)
Unemp	-8.259** (3.653)	-8.064** (3.639)	-8.242** (3.667)	-8.181** (3.597)	-8.209** (3.650)

Table 6: Effect of Weather Events on Murder Rates

Murder Rate	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
# Total Events	3.33E-06 3.04E-04				
# Drought Events		-3.23E-04 3.82E-04			
# Heat Events			-0.001 0.001		
# Rain Events				-3.21E-04 0.003	
# Flood Events					-7.75E-4** 3.57E-04
Income	-0.095 0.161	-0.096 0.162	-0.096 0.162	-0.095 0.162	-0.096 0.162
Population	1.08E-04 0.026	0.002 0.027	7.15E-05 0.027	3.01E-04 0.027	-4.90E-05 0.027
Unemp	-0.094 0.159	-0.098 0.159	-0.093 0.159	-0.094 0.158	-0.093 0.158

Table 7: Effect of Weather Events on Rape Rates

Rape Rate	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
# Total Events	0.002** 0.001				
# Drought Events		0.002 0.001			
# Heat Events			0.006 0.005		
# Rain Events				0.0185* 0.010	
# Flood Events					0.0047* 0.002
Income	0.274** 0.126	0.265** 0.125	0.264** 0.125	0.267** 0.123	0.267** 0.126
Population	-0.131** 0.065	-0.132* 0.070	-0.121* 0.069	-0.129* 0.069	-.120* 0.068
Unemp	0.317 0.418	0.340 0.436	0.316 0.429	0.329 0.423	0.316 0.428

Table 8: Effect of Weather Events on Robbery Rates

Robbery Rate	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
# Total Events	-0.004 0.005				
# Drought Events		0.0173* 0.010			
# Heat Events			-0.037* 0.022		
# Rain Events				0.002 0.045	
# Flood Events					-0.016 0.012
Income	0.366 0.896	0.413 0.893	0.377 0.895	0.387 0.894	0.371 0.894
Population	-0.666 0.537	-0.795 0.513	-0.685 0.516	-0.684 0.518	-0.687 0.516
Unemp	3.216 2.134	3.390 2.114	3.239 2.134	3.208 2.131	3.225 2.130

Table 9: Effect of Weather Events on Property Crime Rates

Property Crime Rate	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
# Total Events	0.104 0.066				
# Drought Events		0.028 0.138			
# Heat Events			0.305 0.386		
# Rain Events				-1.243 0.885	
# Flood Events					0.226* 0.120
Income	-2.047 9.707	-2.584 9.808	-2.550 9.795	-2.911 9.844	-2.406 9.858
Population	-6.774 6.273	-6.473 7.130	-6.277 6.530	-5.602 6.132	-6.241 6.516
Unemp	36.259 23.481	36.818 23.932	36.257 23.904	36.008 23.930	36.263 23.763

Table 10: Effect of Weather Events on Burglary Rates

Burglary rate	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
# Total Events	0.025 (0.016)				
# Drought Events		0.012 (0.042)			
# Heat Events			0.076 (0.103)		
# Rain Events				-0.157 (0.199)	
# Flood Events					0.044 (0.038)
Income	-2.449 (2.803)	-2.569 (2.829)	-2.568 (2.824)	-2.623 (2.826)	-2.544 (2.832)
Population	-1.651 (1.714)	-1.615 (1.947)	-1.532 (1.777)	-1.449 (1.707)	-1.526 (1.777)
Unemp	7.725 (6.100)	7.918 (6.096)	7.722 (6.114)	7.723 (6.126)	7.737 (6.112)

Table 11: Effect of Weather Events on Larceny Rates

Larceny Rate	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
# Total Events	0.042 0.046				
# Drought Events		-0.045 0.079			
# Heat Events			0.133 0.262		
# Rain Events				-1.332** 0.573	
# Flood Events					0.177** 0.081
Income	-0.236 (5.789)	-0.539 (5.823)	-0.437 (5.820)	-0.774 (5.807)	-0.297 (5.859)
Population	-3.485 (3.762)	-3.002 (4.248)	-3.284 (3.846)	-2.552 (3.466)	-3.251 (3.833)
Unemp	29.171* (17.338)	28.803 (17.412)	29.162 (17.431)	28.729* (16.954)	29.076* (17.291)

Table 12: Effect of Weather Events on Motor Vehicle Theft Rates

MV Theft Rate	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
# Total Events	0.037*** (0.013)				
# Drought Events		0.061* (0.031)			
# Heat Events			0.096 (0.065)		
# Rain Events				0.245 (0.193)	
# Flood Events					0.005 (0.027)
Income	0.628 (3.991)	0.513 (4.055)	0.445 (4.049)	0.476 (4.023)	0.425 (4.063)
Population	-1.639 (1.214)	-1.856 (1.332)	-1.462 (1.319)	-1.602 (1.340)	-1.465 (1.319)
Unemp	-0.499 (8.284)	0.233 (8.544)	-0.488 (8.531)	-0.306 (8.409)	-0.411 (8.549)

Appendix

Table 13: Effect of Weather Events on Violent Crime Controlling for Education

Violent Rate	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
# Total Events	-0.006 0.005				
# Drought Events		-0.001 0.011			
# Heat Events			-0.007 0.040		
# Rain Events				0.017 0.102	
# Flood Events					-0.006 0.013
Income	1.455 1.744	1.410 1.741	1.416 1.741	1.402 1.740	1.403 1.736
Population	-2.704* 1.466	-2.805* 1.549	-2.829* 1.502	-2.841* 1.438	-2.883* 1.540
Unemp	-5.432 3.984	-5.363 3.995	-5.349 3.998	-5.367 3.989	-5.300 4.001
Education	-9.574 6.459	-9.831 6.555	-9.780 6.512	-9.897 6.644	-9.847 6.547

Table 14: Effect of Weather Events on Property Crime Controlling for Education

Property Crime Rate	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
# Total Events	-0.006 0.031				
# Drought Events		-0.030 0.076			
# Heat Events			-0.128 0.140		
# Rain Events				0.084 0.591	
# Flood Events					0.048 0.069
Income	11.593 7.059	11.602 7.125	11.615 7.068	11.514 7.114	11.599 7.124
Population	-12.816** 5.321	-12.289** 5.641	-13.006** 5.270	-13.029** 5.373	-12.421** 5.456
Unemp	-2.568 28.575	-2.667 28.519	-2.405 28.450	-2.539 28.514	-2.975 28.516
Education	-21.058 37.632	-21.207 37.847	-20.800 37.809	-21.618 37.189	-21.202 37.844

Table 15: Effect of Weather Events Not Controlling for Population

Violent Rate	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
# Total Events	0.001 0.015				
# Drought Events		-0.016 0.023			
# Heat Events			-0.025 0.076		
# Rain Events				0.070 0.196	
# Flood Events					-0.034 0.032
Income	1.605 3.118	1.575 3.137	1.591 3.137	1.613 3.125	1.564 3.136
Unemp	-7.047 5.363	-7.136 5.339	-7.019 5.346	-7.038 5.294	-7.006 5.341

Table 16: Effect of Weather Events Not Controlling for Population

Property Crime Rate	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
# Total Events	0.093 0.068				
# Drought Events		-0.071 0.105			
# Heat Events			0.311 0.384		
# Rain Events				-1.403 0.985	
# Flood Events					0.232* 0.121
Income	-2.184 9.694	-2.803 9.788	-2.621 9.787	-3.010 9.839	-2.471 9.853
Unemp	31.568 23.380	31.677 23.774	31.848 23.677	32.074 23.725	31.878 23.489

Table 17: Effect of Weather Events on Violence Rate with Time trend

Violent Rate	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
# Total Events	-0.009 0.012				
# Drought Events		0.035 0.022			
# Heat Events			-0.120* 0.067		
# Rain Events				0.121 0.136	
# Flood Events					-0.072** 0.032
Income	1.327 2.979	1.410 2.971	1.310 2.969	1.363 2.954	1.317 2.972
Population	-3.372** 1.554	-3.643** 1.495	-3.426** 1.513	-3.487** 1.532	-3.429** 1.508
Unemp	1.645 2.959	2.035 3.039	1.977 3.092	1.874 3.028	1.729 3.058

Table 18: Effect of Weather Events on Property Crime Rate with Time trend

Property Crime Rate	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
# Total Events	0.057 0.051				
# Drought Events		0.050 0.125			
# Heat Events			-0.128 0.324		
# Rain Events				-1.257 0.876	
# Flood Events					0.160 0.104
Income	-6.575 9.154	-6.489 9.160	-6.623 9.162	-6.937 9.164	-6.570 9.190
Population	-7.030 6.370	-7.030 6.960	-6.720 6.500	-6.040 6.100	-6.700 6.480
Unemp	28.441*** 10.221	27.901*** 10.247	27.754** 10.529	26.639** 10.262	27.676*** 10.367

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